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(54) Abstract Title
Hydraulic pile driving for long piles

(57) A hydraulic pile driving apparatus (10) includes at least two hydraulic units (20, 30) in series. A third hydraulic unit (70) may be arranged in parallel with hydraulic unit (30). When a pile (11) is to be driven, the lower hydraulic unit (20) is compressed followed by compression of the second hydraulic unit (30). When the third unit (70) is present, this is then actuated to extend the jack drive head (50) and the ram (52). This arrangement allows for longer piles to be driven. An attachment may be present on the ram head (52) to allow a pile to be hoisted prior to commencing piling.

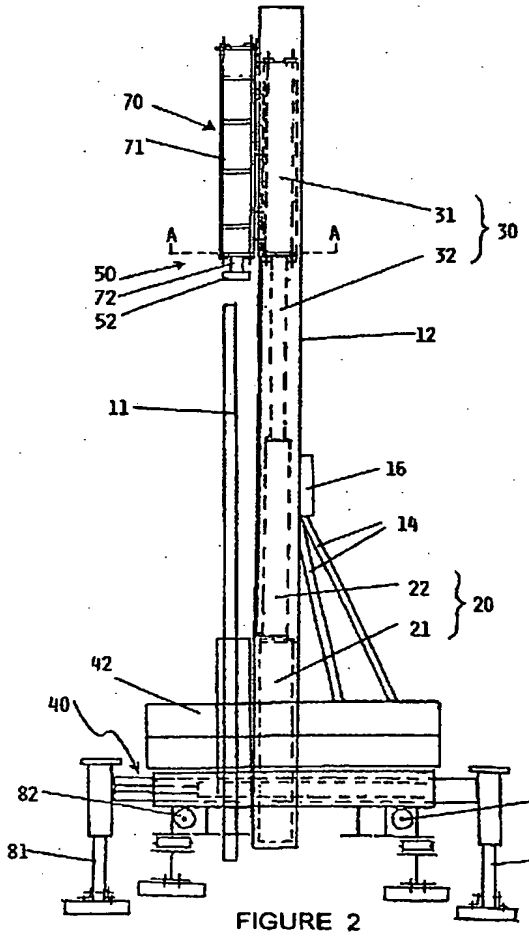

FIGURE 2

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

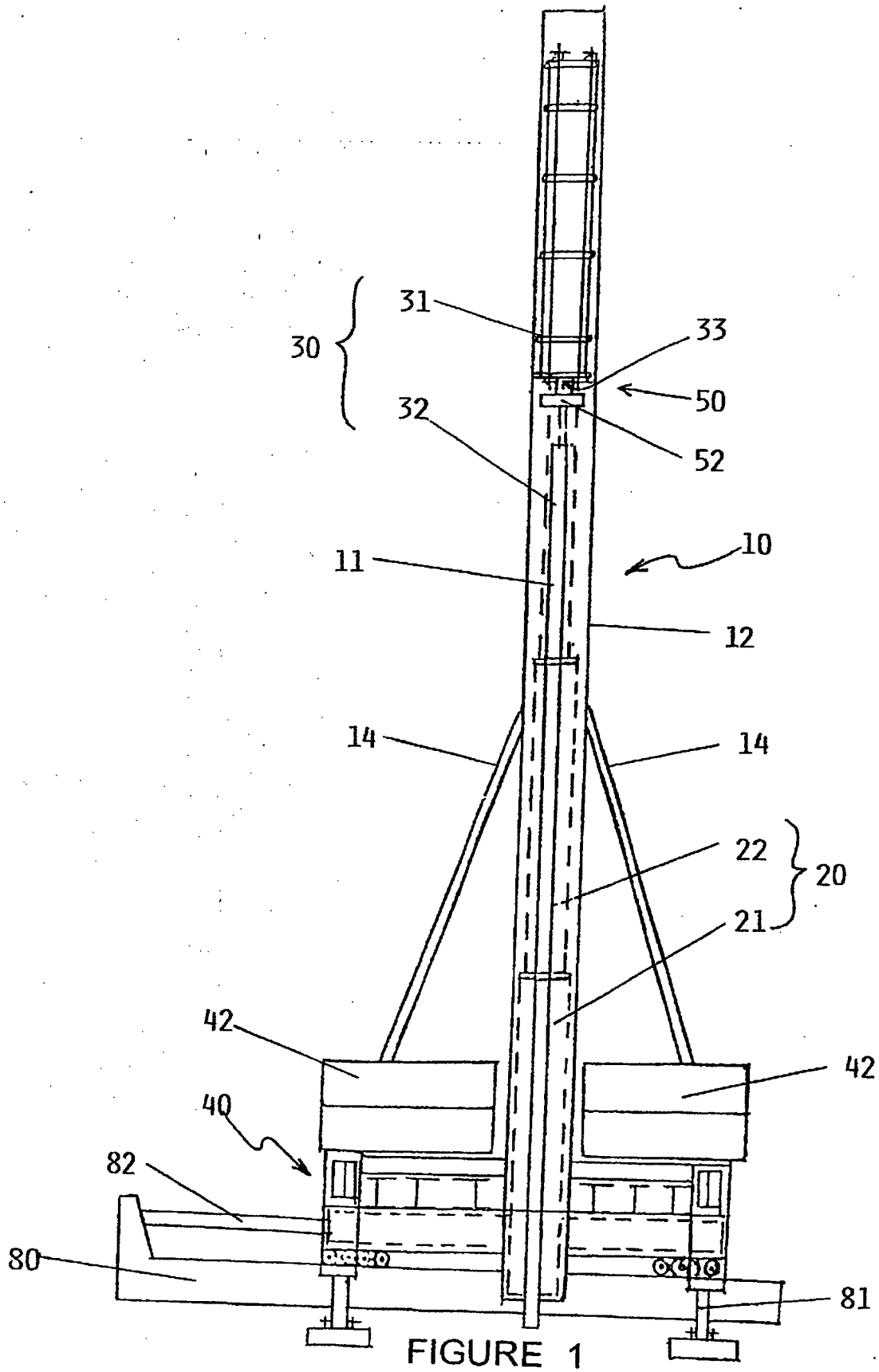

FIGURE 1

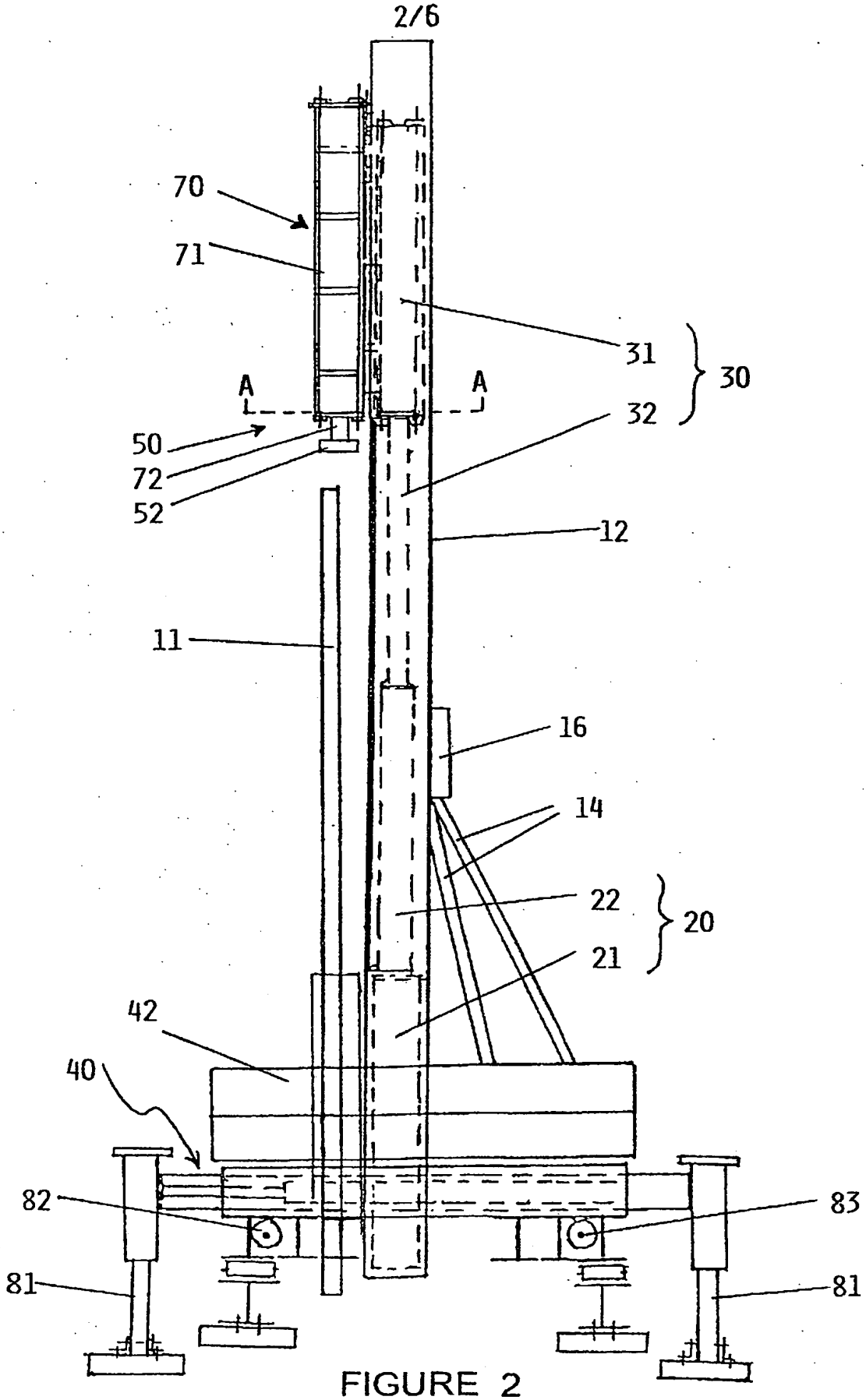

FIGURE 2

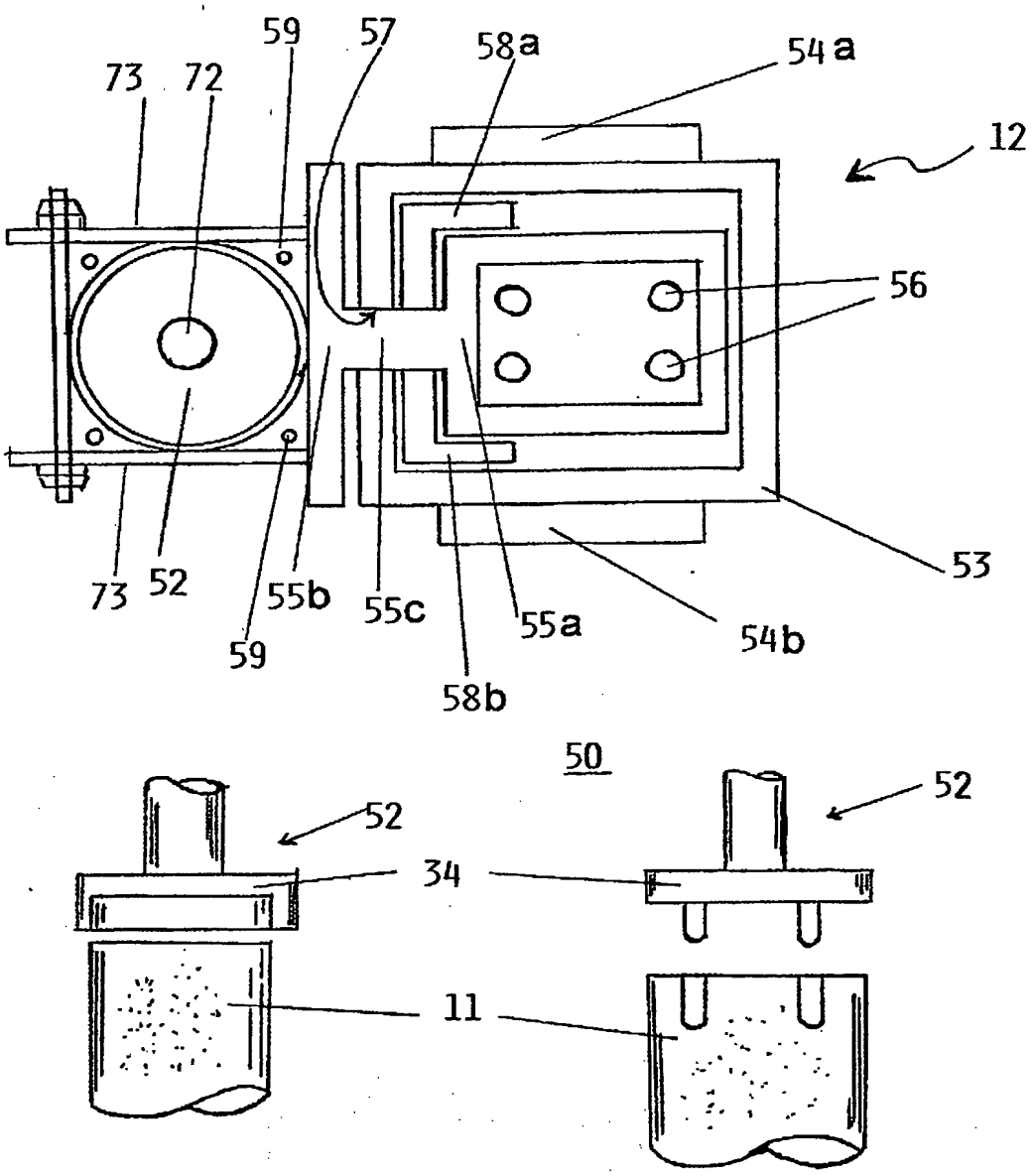
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FIGURE 3

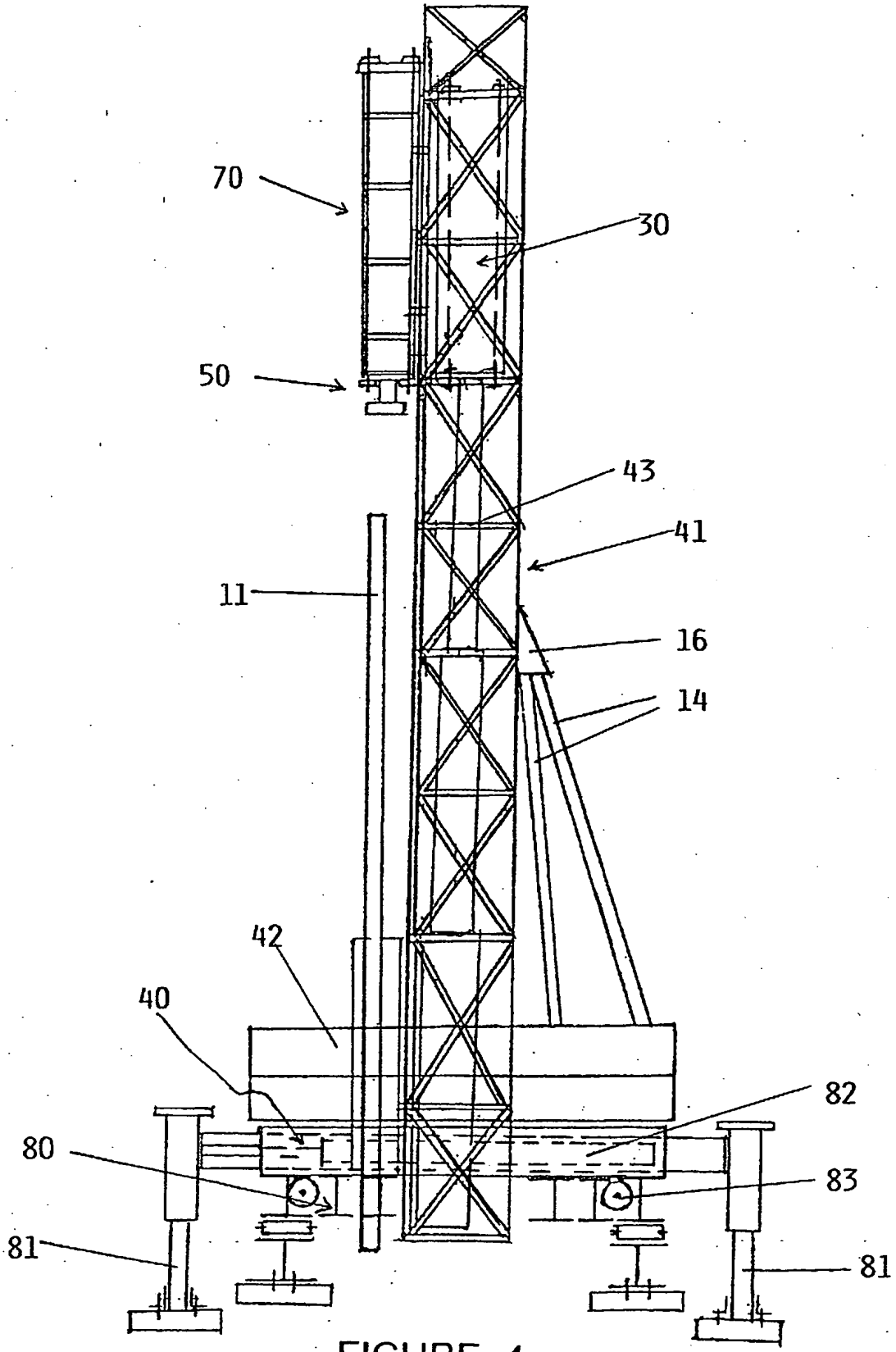

FIGURE 4

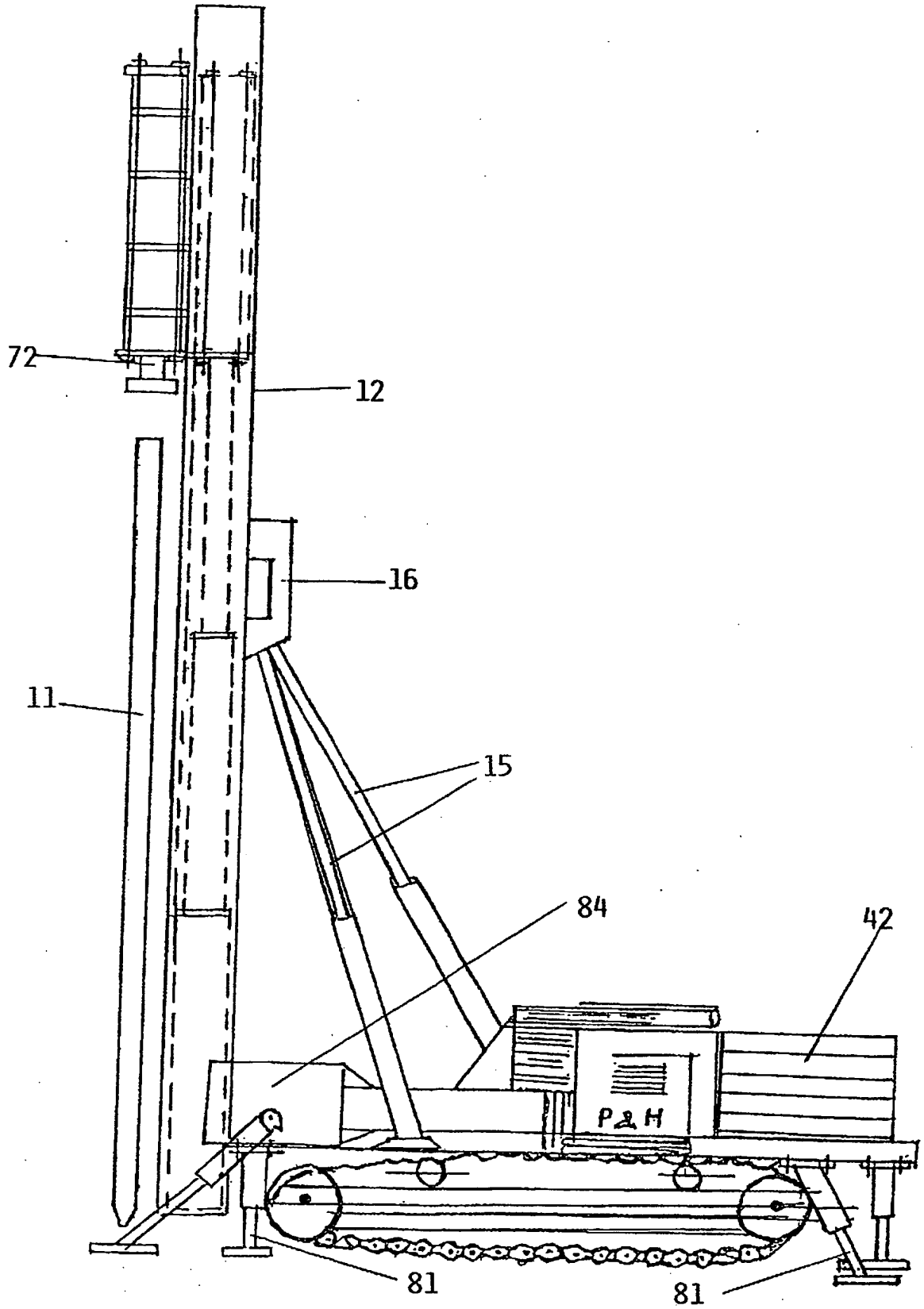

FIGURE 5

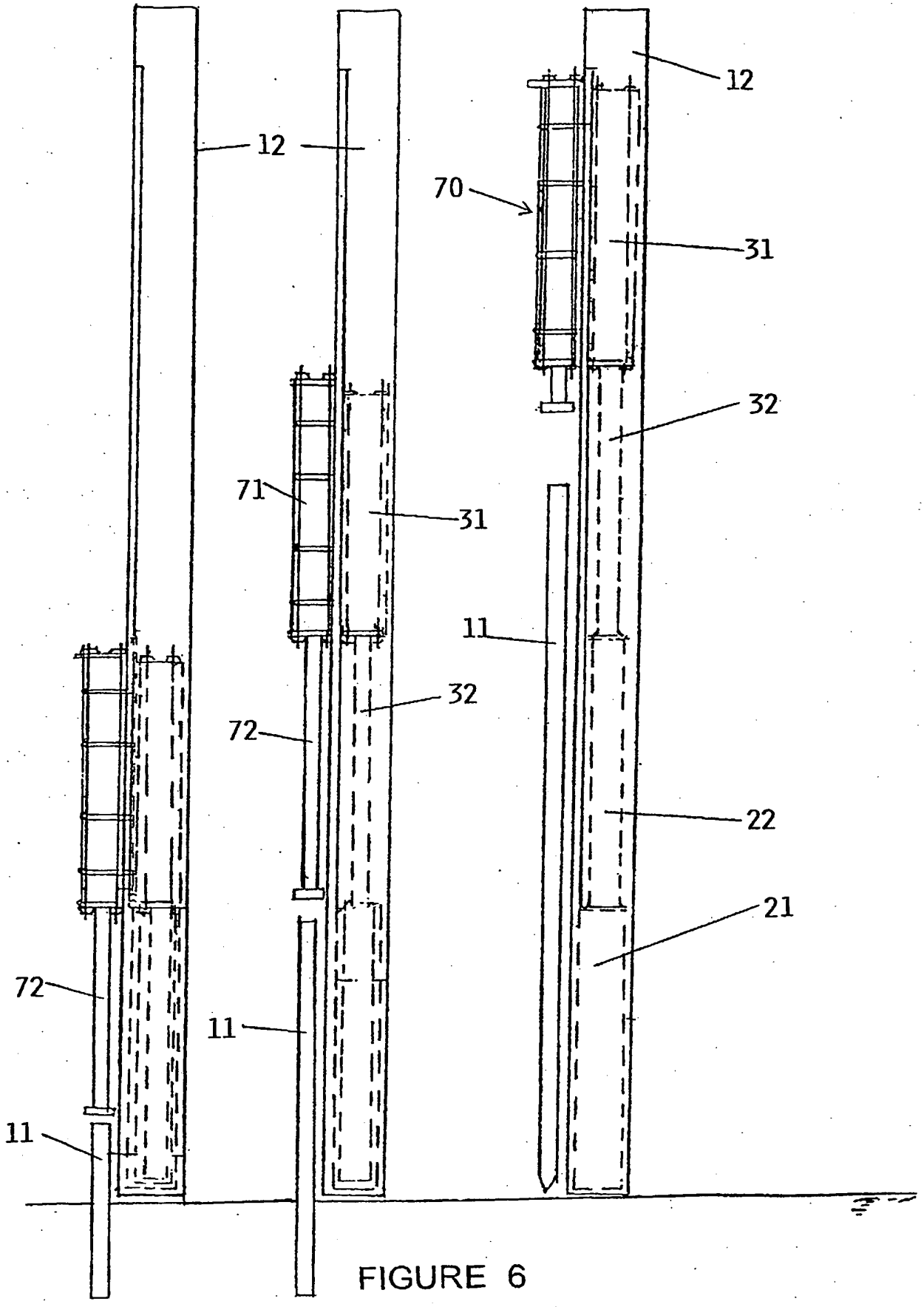

FIGURE 6

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PILE DRIVING APPARATUS AND METHOD

TECHNICAL FIELD

This invention relates to an apparatus for driving piles into the soil, in particular to hydraulic driving means, where continuous jacking pressure is desired instead of vibration or hammering impact force.

BACKGROUND ART

Hydraulically driven pile driving apparatuses are known in the art for some time and are employed where piling is required with no significant vibration or impact noise generated. The prior art apparatuses generally use hydraulic jacking means to bear down directly on the top end of a pile to drive it into the ground.

Among the disadvantages of the prior art hydraulic pile driving apparatuses are the jacking force of most hydraulic units may only be sufficient to jack in the pile if there is a base for the force to act against in order that the reaction force may be transmitted to the pile end. Hence, the prior art apparatuses provide for arrangements wherein the jacking force is reacted against the pile from a counter-weighing Kentledge or ballast, or the building structure's foundation underpinnings itself. This limits the size and length of pile sections that may be driven.

Another disadvantage is the limited length of a stroke of the piston of a hydraulic cylinder. This means that to install a single pile column to the requisite depth in the soil (e.g. to hit the bedrock stratum), the pile column must be installed in the form of several sections short enough to be jacked by a downward stroke of the piston of the hydraulic cylinder. Each sections' steel connecting ends may have to be connected together, e.g. by welded the steel end plates together, before the next section is driven.

To overcome some of these disadvantages, some prior art apparatuses proposed that the hydraulic drive means be raised to a height sufficient to jack a longer pile. For

example, US-5,040,927 (Wickberg) where the opposing force is transmitted along a leader frame hosting the hydraulic drive means to other frame members and base vehicle which has to be weighed down with counterweights. It requires the use of a dolly equivalent, i.e. an alignment piece and ram means so that the length of the pile could be driven to overcome the limit of the piston stroke of the hydraulic cylinder.

In Reissued No. 35,165 of US-5,161,625 (Kong), it is disclosed an arrangement of the pile driving apparatus which enables the pile to be jacked fully into the ground in two strokes. After the first stroke, the pile would now be half-embedded in the ground. The piston and ram are withdrawn and a horizontal arm, hinged to the base frame, is lifted to vertical position to insert a dolly (which length is half of that of the pile and which critical embodiment was not disclosed) between the top of the half-embedded pile and the ram. In the second stroke, the jacking force exerted by the piston and ram on the dolly is transmitted to the pile to embed its remaining half length into the ground.

In the inventor's own GB-2,261,008 (Wu Bong), a parallel arrangement of two hydraulic units which retraction of the pistons bring down a third hydraulic unit which is inverted so that its downwardly extending piston may act as a ram as well as completing the jacking of pile that is twice the length of each of the hydraulic units' fully extended piston in a single combined downstroke.

OBJECTS OF THE INVENTION

To overcome the above limitations, particularly the limitation on the length of the pile that may be jacked in a single stroke by the hydraulic piston's length, the present invention now proposes a novel arrangement of multiple hydraulic units so that a pile length of up to 3 times the length of the piston stroke may be driven into the ground in a single combined downstroke.

The present invention achieves this object without the need for any dolly to complete the jacking of the pile completely into the ground.

SUMMARY OF INVENTION

The present invention discloses a pile driving apparatus for applying continuous hydraulic pressure for driving a pile into the ground. The apparatus comprises a vertically arranged hydraulic drive means which comprises of multiple telescopic sections which are combination of at least two serially arranged hydraulic units wherein the second hydraulic unit is attached to the end of first telescopic piston. Hydraulic pump and controls for operating the hydraulic drive means are also provided.

The apparatus further includes a drive head means and a ram means for jacking the top end of a pile to be driven. The drive head means is connected, at one proximal end, to the cylindrical housing of said second hydraulic unit and, at the other distal end, to said ram means. The ram means is provided to downwardly engage and jack the top end of a pile to be driven. The apparatus also includes a base frame whereupon the first cylindrical housing may be mounted.

In one preferred embodiment, the hydraulic drive means is housed within a vertical frame mounted to the base frame. Adjustable prop means may be provided to hold the base frame and hydraulic drive means to the base frame at a desired alignment in driving the pile at the desired inclination into the ground. Means for aligning the pile at a desired inclination to be driven by said ram means might also be provided.

In another preferred embodiment, the drive head means, in a first position, may be adapted to pivotally hold the top end of a pile to be hoisted up and be positioned erect ready for engagement with the ram means. In a second position, the ram means may be adapted to securely hold to cap said pile's top end in a complementary recess in a position for driving.

In the most preferred embodiment, a third hydraulic unit is provided parallel to second hydraulic unit. The third hydraulic unit is inverted so that the telescopic piston is extendable downwardly. The drive head means may be mounted to the distal end of said telescopic piston.

Still another preferred embodiment, the apparatus's base frame may be slidably mounted on an anchor platform. The base frame may be provided with horizontal hydraulic jacking means to slidably move said base frame against the platform so as to place the foot end of a pile to a desired spot on the ground and at a desired inclination to complement inclination set with the propping means. Preferably still, the apparatus is mounted on a heavy-duty mobile vehicle such as a tracker or backhoe.

The method for driving a pile into the ground using a pile driving apparatus according to the present invention comprises any one or combination of the steps of:

- hoisting up of the pile by its top end by the drive head means and fully extending the hydraulic driving means;
- fitting ram head onto the top end of pile and hold said pile against the vertical frame means;
- adjust the inclination and alignment of the pile and hydraulic driving means prior to driving;
- actuating the first hydraulic unit into compression to jack the drive head and ram means so as to drive the pile into the ground;
- actuating to compress the second hydraulic unit to further lower the height of the vertical hydraulic means so as to drive the pile further into the ground; and
- actuating to extend the inverted, parallel third hydraulic unit to drive the pile yet further into the ground.

BRIEF DESCRIPTION OF DRAWINGS

The invention will now be further described in detail by reference to the accompanying drawings that illustrate, by way of example, the preferred embodiments of the apparatus of the present invention.

FIGURE 1 is a front view of an example of the apparatus.

FIGURE 2 is the side view of the apparatus shown in FIG. 1 wherein the base frame is shown raised as a platform from the ground.

FIGURE 3 is the detailed view of the drive head of the apparatus, in particular, the cross-section marked A – A' in FIG. 2

FIGURE 4 shows an embodiment of the apparatus wherein the vertical frame is a trussed box frame.

FIGURE 5 shows the apparatus mounted on a tracker.

FIGURE 6 shows the various stages of the driving of a pile with the method and apparatus of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

The example of the apparatus as illustrated in FIGURE 1 and FIGURE 2 comprises of a hydraulic drive means (10) vertically arranged. The hydraulic drive means (10) comprises of two serially arranged hydraulic units (20, 30). Both the first or lower (20) and second or higher (30) units are each comprised of a cylindrical housing (21, 31) and a telescopic piston (22, 32) extendable from their respective cylindrical housings (21, 31). The cylindrical housing (21) of the first hydraulic unit (20) is mounted on a base frame (40) while the first telescopic piston (22) may be operated to extend upwardly from the cylindrical housing (21). The top end of the piston (22) is joined to the end of the telescopic piston (32) of the second hydraulic unit (30) which is inverted so that the second telescopic piston (32) may be operated to extend downwardly from its cylindrical housing (31). One or more hydraulic pumps and controls therefor may be provided to operate each of the hydraulic units.

A pile (11) to be driven is placed vertically and parallel to the hydraulic drive means (10). To translate or transmit the compression force as the pistons (22, 32) of each hydraulic units (20, 30) are withdrawn into their respective cylindrical housing, a drive head means (50) may be provided to be attached to the most advantageous position on the higher, i.e. second hydraulic unit (30). In the present embodiment in FIGs. 1 and 2, the drive head means (50) is affixed at its proximal end to the collar (33) of the inverted second cylindrical housing (31) so that the downward force of the hydraulic drive means (10) may be transmitted via its distal end downwards to a ram means (52) engaging the top end of the pile (11) which is placed parallel to the hydraulic drive means (10).

Each of the hydraulic units (20, 30) may be suitably chosen from a wide range of hydraulic units available in the market with respect to the length of piston extension,

diameter and compressive force. In the present preferred embodiment, the hydraulic units have pistons of 40 cm (about 16") in diameter and a maximum piston extension length of about 4.27 m (about 14 ft). Therefore, in a fully extended position, the hydraulic drive unit (10) may accommodate a 12.2 m (about 40 ft) long pile with about 61 cm (2 ft) space above the pile to spare for the ram means (52).

The hydraulic drive means (10) may be housed inside a vertical frame (12) that may be securely mounted to the base frame (40). The vertical frame (12) may be fabricated from, for example, a mild steel box pipe as shown in FIGs. 1 and 2 or a mild steel trussed framework (41) of L-shaped members (42) as shown in FIG. 4. In FIGs. 1 and 2, the mild steel box pipe has the dimension of about 61 cm × 76 cm × 2 cm [24" × 30" × ¾" (thick)].

To further strengthen the frame (12) vertically, prop means (14) may be provided to brace the vertical frame (12) at attachment flanges (16) against the base frame (40). The prop means (14) is preferably with nut-and-bolt adjustable means so that the vertical frame (12) and the hydraulic drive means (10) may be braced at a desired inclination to drive the pile at such inclination into the soil, for example in the foundation for a cantilever bridge. Preferably, the vertical frame (12) includes centring means for holding or supporting the pile (11) at the desired inclination for driving. To counter the reaction force of the jacking, counterweights (42) in the form of Kentledge, ballast or removable and stackable weight blocks may be place on the base frame (40).

The drive head means (50) is shown in detail in FIGURE 3 which is the cross sectional view at plane A – A' of FIG. 2. The vertical frame (12) is comprised of a vertical mild-steel box-pipe (53) held in between a pair of vertical steel plates (54a, 54b). A drive transmission plate (55) is provided whereby its proximal end (55a) is adapted to a square shape plate ending and bolted (56) to the end of the second telescopic piston (32) so that the proximal end (55a) moves slidably through the inside of the box pipe (53).

A guide slit (57) is provided horizontally along the box pipe (53) so that the intermediate I-shape portion (55c) of the plate may slide therethrough. A pair of guiding brackets (58a, 58b) may be provided in the box pipe (53) as shown to provide alignment for the sliding movement of the drive head means (50) along the box pipe (53). The distal

end of the plate (55b) may be adapted to a T-shaped cross-section and affixed to a ram means (52).

In the most preferred embodiment, a third hydraulic unit (70) is provided parallel to the second hydraulic unit (30) whereby the third hydraulic unit (70) is also inverted, as in the case of the second hydraulic unit (30), so that its telescopic piston may extend downwardly when actuated. The third hydraulic unit (70) may be the same type of hydraulic units as the first and second, i.e. having a piston diameter of 40 cm (about 16").

The ram means (52) may be mounted downwardly to the distal end of the third telescopic piston (72). The third cylindrical housing (71) of the third hydraulic unit may be held to the distal end of the transmission plate (55) in between a pair of vertical plates (73) connected to the T-shaped distal end of the transmission plate (55). The inverted top end and collar of the third hydraulic unit (7) may be secured to the transmission plate (55) at the distal end (55b) by bolting means (59). In this embodiment, both the second (30) and the third (70) hydraulic units are thus inverted and joined to one another in a parallel, side-by-side arrangement whereby each units' telescopic pistons extend downwardly.

To place a pile (11) in a position to be driven by the apparatus (not shown), the drive head means (50) may be adapted to a first position enabling it to pivotally hold the top end of a pile, e.g. by hooking onto an eyelet opening provided at the end of the pile's top end. The pile may then be hoisted up with the drive head means (50) when the hydraulic drive means (10) is fully extended and the third hydraulic unit fully compressed. When the pile has been positioned accordingly to be driven, the drive head means (50) may be switched to a second position to become non-pivotal or fixed. The ram means (52) may then be positioned to engage or securely hold the pile's top end in a complementary recess (not shown). Hence, the pile driving apparatus may be adapted for used for any pile type by changing and fixing the appropriate ram piece (34). It is expected that the embodiment of the apparatus illustrated herein would be able to drive a pile diameter in the range of about 15.25 cm × 15.25 cm (6" × 6") to 45.75 cm × 45.75 cm (18" × 18"), including piles that are prestressed.

In FIGURE 4, the vertical frame (12) is shown as a trussed framework (41) comprising of a plurality of mild steel L-shaped brackets (43) joined by steel trusses to

form a vertical metal framework over the hydraulic drive means (10). It would be appreciated that there are many varieties of possible vertical frame designs to effectively cover and shield the hydraulic drive means and to provide a guide means for the downwards jacking movement of the drive head means (50).

In yet another preferred embodiment, as shown in FIGs. 1, 2 and 4, the base frame (40) may be configured to slidably mount on an anchor platform (80). The base frame may be slidably mounted on a platform from the ground level, as shown in FIG. 2, when the anchoring means (81) in the form of hydraulic jacks are extended. A pair of horizontally extending hydraulic jacking means (82) are provided to slidably move the base frame (40) on roller means (83) along the anchor platform in order to place the foot end of a pile to a desired spot on the ground. For such lateral jacking force, it is suggested that hydraulic jacks of about 20.3 cm (8") piston diameter be used. Anchoring jacks (81) are provided to stably anchor the apparatus to the ground. When the horizontal jacks (82) are operated complementary with the adjustable prop means (14), the desired inclination of the drive may be set.

FIGURE 5 shows the pile driving apparatus of the present invention mounted on a heavy-duty vehicle, i.e. a tracker. The adjustable prop means (14) are replaced by hydraulic jacks (15) wherein the piston ends are attached to an attachment flange (16) on the vertical frame (12) while the cylindrical housings are attached to the chassis of the vehicle. It is suggested that hydraulic cylinders of about 17.8cm (7") diameter would be sufficient for the purpose. The bottom portion of the vertical frame (12) and hydraulic drive means (10) are held rigidly by a horizontal arm (84) extended forward from the vehicle's chassis. Anchoring jacks (81) are provided to anchor the vehicle to ground. Counterweights (42) are provided at the distal end of the vehicle to obtain the maximum leverage.

FIGURE 6 shows the preferred steps in which a pile is driven into the soil with the apparatus of this invention. The preferred steps comprise of the following:

- hoisting up of the pile (11) by its top end by the drive head means (50) and fully extending the hydraulic driving means (10) as explained in the foregoing;
- fitting ram head (52) onto the top end of pile (11) and hold said pile (11) against the vertical frame means (12) , and

- adjust the inclination and alignment of the pile and hydraulic driving means prior to driving (not shown).
- actuating the first hydraulic unit (20) into compression to jack the drive head (50) and ram means (52) so as to drive the pile (11) into the ground;
- actuating the second hydraulic unit (30) into compression to further jack the drive head (50) and ram means (52) so as to drive the pile (11) further into the ground;
- actuating the inverted, parallel third hydraulic unit (70) into extension to jack the drive head (50) and ram means (52) to complete driving the pile into the ground.

It will be apparent to a person skilled in the art that the specific embodiments described hereinabove may be varied or substituted with equivalent parts or components that are not specifically described herein. These equivalents, variations or substitutes may be used to effectively work the concept and working principles of this invention and they are not to be considered as departures from the present invention and shall be considered as falling within the letter and spirit of the following claims.

CLAIMS

1. A pile driving apparatus for applying continuous hydraulic pressure for driving a pile into the ground comprising -

- a hydraulic drive means arranged substantially vertically and comprises of multiple telescopic sections being combination of at least two serially arranged hydraulic units wherein
  - a first hydraulic unit is comprised of a first cylindrical housing for a first telescopic piston extendible upwardly therefrom;
  - at least a second hydraulic unit comprised of a second cylindrical housing for a telescopic piston extendible longitudinally therefrom,
  said second hydraulic unit is attached to the end of first telescopic piston;
- a drive head means;
- a ram means for jacking the top end of a pile to be driven,
  wherein said drive head means is connected, at one proximal end, to the cylindrical housing of said second hydraulic unit and, at the other distal end, to said ram means,
  and wherein said ram means is provided to downwardly engage to jack the top end of a pile to be driven;
- a base frame whereupon the first cylindrical housing is mounted; and
- at least one hydraulic pump and controls for operating said hydraulic drive means.

2. A pile driving apparatus according to Claim 1 wherein the hydraulic drive means is housed within a vertical frame mounted to the base frame.

3. A pile driving apparatus according to Claim 2 wherein adjustable propping means are provided to hold the base frame and hydraulic drive means to the base frame at a desired alignment in driving the pile at the desired inclination into the ground.

4. A pile driving apparatus according to Claim 3 wherein the vertical frame includes means for aligning a pile in place at a desired inclination to be driven by said ram means.

5. A pile driving apparatus according to Claim 1 wherein the drive head means, in a first position, is adapted to pivotally hold the top end of a pile to be hoisted up and to be

positioned erect ready for engagement with the ram means; in a second position, the ram means is adapted to securely hold and cap said pile's top end in a complementary recess in a position for driving.

6. A pile driving apparatus according to any one of the preceding claims wherein a third hydraulic unit is provided parallel to second hydraulic unit, said third hydraulic unit is inverted so that the telescopic piston is extendable downwardly, and wherein the ram means is mounted to the distal end of said telescopic piston.

7. A pile driving apparatus according to Claim 6 wherein the base frame is slidably mounted on an anchor platform and is provided with horizontal hydraulic jacking means to slidably move said base frame to place the foot end of a pile to a desired spot on the ground and at a desired inclination to complement with the propping means according to Claim 3.

8. A pile driving apparatus according to Claim 7 wherein the apparatus is mounted on a heavy-duty mobile vehicle, including any one of a tracker and backhoe.

9. A method for driving a pile into the ground using a pile driving apparatus according to any one of the preceding claims.

10. A method according to Claim 9 comprising the steps of :

- actuating the first hydraulic unit (20) into compression to jack the drive head (50) and ram means (52) so as to drive the pile (11) into the ground;
- actuating to compress the second hydraulic unit to further lower the height of the vertical hydraulic means so as to drive the pile further into the ground; and
- actuating to extend the inverted, parallel third hydraulic unit to drive the pile yet further into the ground.

11. A method for driving a pile into the ground further including any one of the following steps prior to the method of Claim 10:

- hoisting up of the pile by its top end by the drive head means and fully extending the hydraulic driving means;

- fitting ram head onto the top end of pile and hold said pile against the vertical frame means, and
- adjust the inclination and alignment of the pile and hydraulic driving means prior to driving.

12. A pile installed with a method according to Claim 9 or with a pile driving apparatus according to any one of Claims 1 to 8.

13. A building site wherein at least one pile therein has been installed with a method according to any one of Claims 9 – 11 or with a pile driving apparatus according to Claims 1 – 8.

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Application No: GB 0121938.5
Claims searched: 1-13

Examiner: Dr. Lyndon Ellis
Date of search: 14 January 2002

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.T): E1H HGH

Int Cl (Ed.7): E02D

Other: Online: EPODOC, WPI, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	GB 2291911 A (Bong Wu)	-

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.